# STATUS REPORT ON OPERATION AND UPGRADING OF THE UNILAC

N. Angert and D. Böhne
GSI, Gesellschaft für Schwerionenforschung mbH
D-6100 Darmstadt, Fed. Rep. of Germany

## Summary

A review is given on five years of operation of the Unilac heavy ion linear accelerator. Important developments of subsystems and their present status are described. The current upgrading, initiated mainly to increase the output energy to 20 MeV/u for the heaviest elements, includes also an extensive improvement program of existing equipment. The injector beam line is completely reconstructed in order to increase the radial acceptance by a factor of three, and, in addition, part of the control system is prepared for multi-beam operation.

## Introduction

Experiments with the Unilac started in 1976. The first Uranium beam was accelerated by beginning of April 1976. The development of operation and the performance of components were described in a previous status report.[1] References for the different parts of the machine and for special features are given there, too. More recent research and development activities as measurements of the Wideröe space charge limit, beam diagnostic and rf high power amplifiers have been reported elsewhere.[2,3,4,5] A five months shut down from August'81 to January 1982 will be used to increase the energy of the Unilac by adding two Alvarez tanks. Details have been outlined in a previous paper.[6]

## Unilac Operation

The development of Unilac operation statistics can be seen from figure 1, which displays the time fractions of the total operation time since 1976. Target time means beam on target for production runs of the main experiment. Retuning of source or beam transport is not included, nor the number of parasitic target hours which are possible due to the beam splitting system. The tune-up time contains both the tuning of the accelerator and the transport and matching to the experiment. Unscheduled down time is not only accounted for hardware failures but also for time lost by unduely strong plasma oscillations of the ion source or retuning difficulties of the operation crew.

The fraction of target time was continuously increasing since the commissioning in 1976. The efficiency in the first year was affected by initial five days instead of seven days operation and major problems with rf-components and magnet power supplies. Target time was increased further in 1977 despite a decreasing reliability of some components. The two shut downs of four to six weeks each per year were dedicated to necessary improvements or completions of equipment but there was hardly time for extensive check-out of new equipment nor for accelerator experiments. In 1978 more shifts for accelerator experiments, development and additional

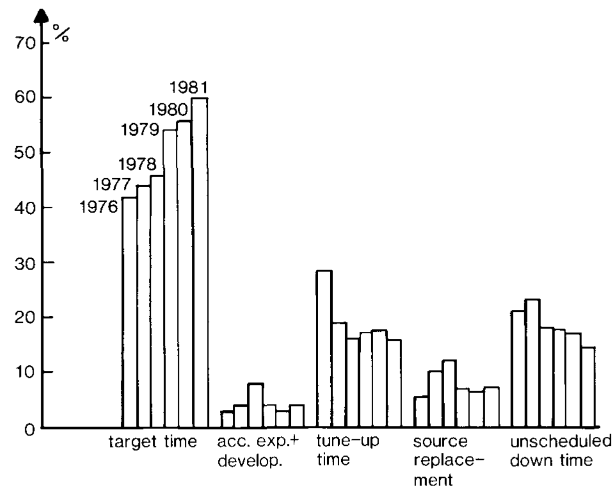


Fig. 1: Statistics of five years Unilac operation

short-term maintenance were introduced resulting in a significant reduction of unscheduled down time. Also the tuning time went down despite the introduction of the beam splitting and increasing demand for good micro structure of the beam with respect to time and energy width of beam bunches needing especially careful tuning of the machine. As the major hardware improvement programs had been finished it was decided to change the schedule by beginning of 1979. Every fourth week was then scheduled for maintenance and development. Maintenance and improvement work is partially done in shifts. This operation rhythm proved favourable for the Unilac and led finally to about 60 percent target time in 1981. This figure corresponds to about 75 % of scheduled time. The fraction of parasitic target hours is in the range of 25 to 30 % of total operation time. Beams for parasitic experiments cannot be provided if the intensity requirements of the main user leave no reserve, if frequent energy changes would take too much tuning time or if multi charge operation is required in the straight through Y-branch for very high intensities.

The increasing support by the computer control system both by off-line and on-line programs had helped to reduce tuning time despite of a significant increase of isotope and energy changes per year since 1979. The connection of rf systems to the computer control and the reconstruction of the injector, which will be described later, will lead to a further improvement in this respect. The latter should also help to reduce the stress of ion sources and the number of replacements. The time lost for source replacement and corresponding retuning is about 1 hour on the average for most of the elements. If sophisticated isotope separation is requested as e.g. for a clean $^{208}$Pb beam from natural material the average is about 2 hours.

In 1981 mainly rf systems, injectors and magnet power supplies contributed to the down time of the Unilac. For the various rf systems the problems are of different nature. The Wideröe amplifiers showed reliable rf performance despite of the fact that they are run up to 40 % above their design values, but the amplifier electronics caused increasingly down times because of corrosion on electronic prints.

During several years tube problems did not allow to run the Alvarez structure at power levels which would be necessary for the acceleration of gas stripped very heavy elements. Within the last two years this situation has changed. Alternate programs for the Alvarez rf amplifiers to achieve 1.6 MW peak power offer now three solutions. Some failures of the presently used tube type have been fixed by the manufacturer, and an alternate tube for the same plate circuit is on the market.[4] In addition, a new final amplifier was developed from an industrial manufacturer with another tube, having successfully demonstrated 1.6 MW at 25 % duty cycle.[5]

The rf amplifiers for the single gap cavity structure could not be operated at the full power ratings in the past because the frequency tuning of the tanks did not have an adequate range. Now, with a new tuning device[9] there are problems with the final amplifier stage at full power.

Down times of the injector are mainly caused by control electronics and ion source failures as short circuits between the sputter electrode and the anode, breaks and deformation of filaments or simply by too poor yield of an ion source.

Two years ago it was anticipated to exchange all magnet power supplies. The original system had 350 power supplies and 65 different types. The development of a thyristor-supply, of which a prototype is powering one inflector magnet, will help to reduce the variety. Accelerator experiments and operation practice have shown that the number of individual supplies for magnets and lenses can be reduced, too. Therefore, the substitution of power supplies will be first limited to the mostly stressed sections as Wideröe tank 1 and the stripper section. In addition, the different types of steerer power supplies have been substituted by one type. For the very unreliable degaussing units an inhouse development was used instead. However, the fraction of down time due to magnet failures is still about 20 %. Half of it is caused by peripheric magnet equipment as thermo-switches and flow meters, and half by power and control electronics, too. A prototype for a new control-interface unit is being tested. It is equipped with a microprocessor and is designed for future multi-beam operation of the Unilac.

The computer system will be stepwise supplemented by microprocessor interfaces. The use of microprocessors should make it possible to move tasks from the local PDP 11 computers to microprocessors, and from the central computer to the PDP-level. One necessary condition for this is the present implementation of the RSX11-M system software for the PDP computers and the corresponding software structure changes. On this basis it should be possible to come to a new computer control configuration by 1985 without affecting the Unilac operation.

## Status of the Upgrading Program

The occasion of the five months shut down necessary for the energy increase of the Unilac[6] was equally used for other important improvements of the Unilac as the modification of the injector beam transport and diagnostics, the installation of a microprocessor system for the computer control of the rf generators and new rf power lines for the whole poststripper accelerator. In addition, major changes are being made in the control electronics of rf generators to improve their reliability.

The new beam transport has been completed now for one of the two injectors. The terminal beam transport has been changed and an additional emittance measurement device was installed at the high voltage platform. The first part of the beam transport line to the Wideröe, which is used for the isotope separation, is now equipped with quadrupoles of 80 mm aperture giving a normalized acceptance of 0.05 cm mr for the whole system. This is three times higher than before. In first test runs with the new beam line peak intensities of up to 1200 μA could be achieved for $Ar^{3+}$ and up to 50 μA for $Pb^{8+}$ and $U^{9+}$ at the Wideröe entrance. The beam diagnostics has been changed accordingly.

All rf generators are being connected to the computer control system via a microprocessor link, which allows for multi-beam operation, too. At the Wideröe section this new control has been already successfully tested with rf.

The helix rebuncher in the stripper section was replaced by a spiral resonator from Frankfurt University. An additional one is being prepared for installation behind the charge analyzing system for an improved matching to the Alvarez structure.

The modification of the poststripper section, the leading activity in the present shut down is already completed: The single gap cavities are moved to the far end of the slightly extended linac tunnel and are now combined into one group of 17 units (see fig. 2). This was necessary to make room for two new Alvarez tanks which are now in place, under vacuum and connected to the utilities, magnet supplies and rf feed lines.

The fabrication of the new tank, described earlier[7], presented no problems: The requested diameter tolerance of $\pm^{1}_{0}$ mm was achieved and the final copper plating[8] of the circumferential welding seams proceeded as determined on a prototype.

Difficulties arose during drift-tube fabrications. The manufacturer omitted the prescribed shoulder fit of the roll-pressed end caps to the cylindrical sheet metal body tubes and applied a too heavy welding seam. This resulted in a length shrinkage of 1 ± 0.5 mm. Because this error was nearly the length increment from cell to cell, each drifttube was installed one cell further upstreams and a new end drift tube was fabricated for both tanks from available spare parts. Some units have been length corrected by copper plating. It was equally necessary to remachine the fit for the alignment target according to the magnetic axis, due to bore tube distortions, resulting from an overly heavy weld.

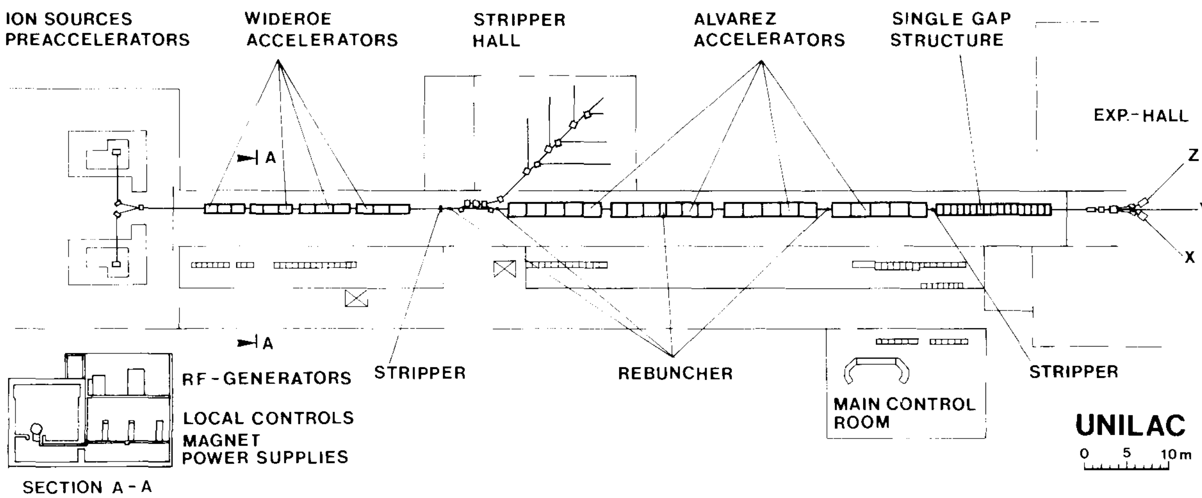


Fig. 2: The Unilac with two additional Alvarez tanks after the upgrading.

Flattening of the field distribution was easy by means of the envisaged fixed tuning bodies. A so far unexplained frequency error of - 100 kHz was corrected for by a previously not foreseen tuning bar. It consists of two plated tubes, 1.7 m in length and 5 cm in diameter, spaced 2 cm apart from the cavity wall by ellbow-shaped endpieces joining blanks at the position of available flange holes. At half length of the tube an additional support had to be supplemented in order to suppress mechanical vibrations. The remaining tube sections, four per cavity and of different length, performed as strip line resonators at or close to the nominal tank frequency and depressed the Q-value. By trimming the individual section lengths, it was then possible to displace their resonant frequency to a presumably adequate value.

The new rf window design, described earlier[9], was easy to fabricate and was tested in a line type resonator. The observed arcing on the atmospheric side was suppressed by supplementary corona rings on both ends of the ceramic insulator tube. Equivalent forward power levels of 4 MW were obtained and 9 MW were obtained with an additional nitrogen flushing of the window area, clearing the ionized atmosphere.

The installation of a new generation of rf power lines is already finished for the Alvarez tanks, while for the single gap cavity structure this activity is still proceeding, as well as the improvements of the control electronics of this subsystem.

The new Alvarez tank IV was run up through severe multipactoring thresholds to the design peak power, rated for gas stripper operation and half of the maximum thermal power. The temporary limitations are due to amplifier and tube malfunctions. No bellow heating was observed on the drifttube stem heads. The aluminum rf and vacuum seals, which are tentatively installed at the end cover joints and which replace the earlier gold wire standard, are performing equally well.

The beam splitting system at the exit of the poststripper had to be shortened by a factor of two, requiring a twice as strong deflection of the first septum magnets. New coils and new 3,800 A power supplies were procured and are tested. The beam line between the end of the single-gap cavities and the beam splitting area is nearly rebuilt.

## References

[1] D. Böhne, Status Report on the Unilac, 1979 Lin. Acc. Conf., Montauk, N.Y., BNL 51134, p. 98.

[2] J. Klabunde et al., High Current Experiments in a Wideröe Structure, 1981 Part. Acc. Conf., Washington, D.C., IEEE Trans. Nucl. Sci., Vol NS-28, No. 3, p. 3452.

[3] P. Strehl et al., A New Emittance Measuring Device of the Unilac, 1981 Part. Acc. Conf., Washington, D.C., IEEE Trans. Nucl. Sci., Vol. NS-28, No. 3, p. 2216.

[4] G. Hutter and N. Angert, Improvement of the 108 MHz RF-Amplifiers for the Unilac Alvarez Structure, 1981 Part. Acc. Conf., Washington, D.C., IEEE Trans. Nucl. Sci., Vol. NS-28, No. 3, p. 3012.

[5] K.H. Knobbe and D. Böhne, A Megawatt RF Source at 108 MHz, 1981 Part. Acc. Conf., Washington, D.C., IEEE Trans. Nucl. Sci., Vol. NS-28, No. 3, p. 3010.

[6] N. Angert et al., The Unilac Upgrading Program, Proc. 1979 Lin. Acc. Conf., Montauk, N.Y., BNL 51134, p. 17.

[7] D. Böhne et al., Cavity and Drifttube Technology for the Upgraded Unilac, Proc. 1979 Lin. Acc. Conf., Montauk, N.Y., BNL 51134, p. 388.

[8] H. Gaiser and D. Böhne, Copper Plating of Small Areas in Large Cavities, 1981 Part. Acc. Conf., Washington, IEEE Trans. Nucl. Sci., Vol. NS-28, No. 3, p. 3002.

[9] D. Böhne et al., Recent Improvements of Accelerator Components at the Unilac, Proc. 1979 Lin. Acc. Conf., Montauk, N.Y., BNL 51134, p. 348.

Discussion

In the rf system, we used the Thompson 518 in the past; there were serious problems but we think they have been solved. The alternate tube for the same plate circuit is the Siemens tube that has been on the market about one year. The new plate circuit developed by industry was based on an Eimac tube.